BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: Common Mission Module - Parametric Sizing Study, Case 730

DATE: July 12, 1968

FROM: A. S. Kiersarsky

ABSTRACT

This study summarizes the results of a preliminary parametric sizing study conducted for the purpose of evaluating the spatial and volumetric capability of common mission hardware to support crew sizes of 2 or more men for a mission period of 2 years duration. The various module sizes and internal configurations are briefly described and graphically illustrated.

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MEMORANDUM FOR FILE

INTRODUCTION

This memorandum generally defines the internal configurations for the common mission module and associated systems, the purpose being, evaluation of the capability for several sizes of common mission modules. Here, it should be noted that selection of systems and their sizes are preliminary and, as such, final sizes and configurations will be, ultimately, dependent on the detail design requirements. Therefore, these configurations are by no means the only possible common mission module design solutions. Also, since this is a sizing study, no attempt was made to solve the detail design problems.

REQUIREMENTS AND ASSUMPTIONS

To approach this study, certain requirements and assumptions were made, these are:

- Mission Duration - Mission periods will be 2 years duration. (Expendable volumes are sized accordingly).
- Crew Size - Module crew complement to be 2 or more men.
- Crew Quarters - Quarters for sleep, rest and personal seclusion will be provided for each crew member. (No attempt has been made to time share crew quarters).
- Hygiene and Waste Disposal - Sanitary Facilities will be provided for crew hygiene and waste disposal. (Water reclamation to be part of EC/LS).
- Food - Food will be provided for the mission period with volume based on 1.5#/Man Day at 15#/Ft^3 density. (Approximately 75 Ft^3/ man for mission).

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From: S. Kiersarsky

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- Food Preparation and Social Area - An area will be allotted to food preparation (galley). The dining area will also be used for social activity.

- Life Support System - A regenerative life support system will be provided incorporating-atmospheric control subsystems such as:

  O_2 recovery
  CO_2 removal
  Thermal and Humidity Control
  Toxin Control
  Air Distribution
  H_2O reclamation (urine & wash)

  (Here volume requirements are assumed since systems presently designed are lab types.)

- Gravity Configuration - The compartments will be arranged for gravity environment except sleep areas. Change of sleep areas from zero to artificial gravity will be accomplished in the same space.

- Micrometeroroid Protection - Protection will be provided for the module pressure shell. (An external structure will be used for the launch environment, and shall incorporate variable micrometeroid protection.

- Airlock & Storm Shelter - A separate airlock compartment with ingress and egress, both to the module compartment and space will be provided. This unit will be capable of supporting the entire module crew for periods of emergency. Also, this compartment will be utilized for EVA (See Figure 1 for sizes).

- Spares - Space will be allotted for spares to maintain on-board systems. (Here the volume allotted, approximately $30 ft^3$, was assumed since no studies have been conducted to determine exact system requirements).

- Recreation - Space will be allotted for recreation conveniences such as T.V., micro-filmed books and viewer, along with other items of recreation. (Again allotted volume, approx. 30 Ft^3, is assumed.)

- Mission Control & Data Management - Space will be provided for two consoles. (Here, a console and floor area was selected which consummed approximately 17 Ft^2. This includes provisions for crew movement.

- Inter-Module Transit - Provisions will be made for inter-module transit, one at each end of the module. (The alternate route of transit will be by EVA through the airlock exit.)

- Docking - Provide docking capability with other modules along the longitudinal center line.

- Power - External to the pressure compartment allot space along the circumferential surface for an Isotopic Power System, and Brayton Cycle Power Conversion Units. The Isotope Unit will be mounted so as to enable emergency heat radiation as well as abort capability.

- Access - The pressure wall of module will be accessible for micrometeoroid repair.

- Compartment Size - Floor to ceiling height will be 6.5 Ft (78").

MISSION MODULE SIZING

Having stated the basic requirements for the mission module configurations, attention was then devoted to the size and types of configurations to be selected. Here the initial consideration was given to size.

The selected candidate diameters for both the external structural shell and the module pressure shell are:

Structural Shell Diameter	Pressure Shell Diameter
1. 15.0 Ft. Diameter	14.0 Ft. Diameter
2. 17.5 Ft. Diameter	16.5 Ft. Diameter
3. 21.67 Ft. Diameter	20.0 Ft. Diameter

The external diameters were selected to be compatible to the presently available boosters. Namely; item 1 above was selected for compatibility with Titan IIIM; item 3 is compatible with the S-IVB stage of Saturn; and item 2 was selected as an intermediate size that could be used with either booster*.

MISSION MODULE TYPES

For the three module diameters, a progressive evolution of arrangements was conducted to determine the exact capability of each module size. This was accomplished by graphic study, using existing or projected subsystem sizes. Three types of deck arrangements were selected and these are as defined below and shown in Figure 2.

Type I - Single Deck with Equipment Bay

This is a single deck arrangement with an equipment bay integrated into one end of the pressure compartment. The deck compartment of the module contains the crew quarters, sanitary facilities, social and dining area, and the airlock. The equipment bay supports the EC/LS, provides stowage for food, recreation equipment and spares. Access to this area will be through removable panels.

Type II - Double Deck

This is a double deck arrangement with no equipment bay. The lower deck is essentially the same as the single deck of Type I, and the upper deck contains the equipment previously located in the equipment bay of Type I. Considerably more floor space and volume are provided by the extra deck. The flexibility of placing equipment and food stores improves accessibility over the equipment bay type configurations.

Type III- Double Deck with Equipment Bay

This is a double deck arrangement with the equipment bay sandwiched between decks. Again, the lower compartment is utilized for crew quarters and their associated requirements such as sanitary

*Items 1 and 2 require TIIIM hammer heading.

facilities, etc. The airlock was relocated to the upper deck. The upper deck also contains certain experiments. The equipment bay is used for support of equipment similarily as in Type I. Accessibility to the equipment compartment is increased (over module Type I), since the crew can gain access from either side through removable panels.

MISSION MODULE CONFIGURATION:

GENERAL

The structural concept of the mission module is an external structural shell, within which is supported the module pressure compartment. Integral to the external structure is the micrometeoroid protection and thermal radiators.

The internal structural arrangement of the module pressure compartment shows an integrally pressurized module, but, for Types II and III, the module decks can be separately pressurized by designing the interface bulkheads and hatches for the internal design pressure.

To each end of the mission module, a docking configuration is incorporated, also, the Isotopic Power Supply is located at one end. For this study, the docking design shown utilizes part of the compartment space made available by the mandatory placement of the Isotopic Re-entry Vehicle (IRV) external to the pressure compartment and on the outer surface of the module configuration. The docking configuration shown is just one method of performing this operation. Also, this space can be utilized for expendable supplies if required.

It should be noted that module length beyond the pressure shell bulkheads (floor and ceiling) is not necessarily set by the docking mechanism since alternate docking devices can be designed. The isotope heat source and expendable volume requirements set module length.

No propulsion units are shown since it is assumed a separate propulsion module would be used. But, operation of a propulsion module can be controlled from inside the module at one of the consoles.

INTERIOR ARRANGEMENTS

There have been many different arrangements configured for space station hardware, and this study presents one possible approach. The attached figures show system equipment and crew quarters arranged to the extent possible, circumferentially, about the exterior walls of the compartments. This provides maximum unit floor space. Within the equipment bays, where used, equipment was distributed more uniformly.

DESIGN CONSIDERATIONS:

CREW QUARTERS

The crew quarters shown in the various configurations are oriented within the module for a zero-gravity condition, but as shown in Figure 3, these can be oriented to a gravity environment. For each crew member, a floor area of approximately 9 ft^2 and a height of 6.5 ft (volume of approximately 60 ft^3) was allocated to the sleep and rest area. Here, the design intent was to integrate the sleeping quarters into a more compact area which, when not in use, as a sleep or rest area, could be used for off duty seclusion to read, study, or just be alone. Adjoining each crew cabin, a gear stowage locker approximately 3 ft^2 and 6.5 ft in height, is located, in which clothing and other personal gear may be stowed.

SANITARY FACILITIES

Separately enclosed areas are provided, one for personal hygiene and the other for waste collection and management. The requirement for H_2O regeneration requires these stations be integrated with the H_2O reclamation system.

SOCIAL AND DINING AREA

Within each module, an area has been allocated for Social and Dining activity. To retain as much floor space as possible, the table and chairs are stowable type gear. This area is located in close proximity to the galley.

AIR LOCK

An air lock is located within each module configuration to provide a protected volume for the crew in event of an emergency, such as fire or solar flares, and to provide ingress and egress capability to the main module compartment from the exterior or space side of the module. The air lock will also be used for EVA activities. Sizing of the air lock, for varying crew sizes, was determined graphically, see Figure 1.

CONSOLES

There are two consoles located in each configuration. The function of these consoles is primary spacecraft control and mission control (i.e., guidance and navigation, communications and data handling, and subsystems monitoring). The consoles are

sized to provide approximately 15 ft^2 of instrument panel space for each. Floor space for each console, including the area of movement for an astronaut, is 17 ft^2.

EC/LS SYSTEMS

An integrated regenerative type system was selected for this study. Here, since it is regenerative, the maintainability of the system will have considerable impact on the size and volume required. Several systems of this type have been designed and fabricated, but instead of selecting a particular system, a representative size and volume was assumed (Table 3).

FOOD

The volume of food is crew and mission dependent with spatial and volumetric requirements fixed from the basic requirements of 1.5#/man-day and 15#/ft^3 density. However, if the complete 2 year food supply is not launched, which is an option for orbital missions, the Type II configuration offers the possibility of considerable space for more crewmen or experiments, see Figure 5 for possible alternate arrangments.

RECREATION AND SPARES

With no firm or definitive requirement, the spatial and volumetric requirement for recreation and spares must be assumed. The floor space assigned to such storage, when no equipment bay was included, is 4.5 ft^2; and a total assigned volume of 30 ft^3 was allotted regardless of the type configuration.

EXPERIMENT

It is the design intent to employ separate experiment or operational function modules. These of course may be additional Common Mission Modules. However, experiments are shown (i.e., biomedical selected for illustrative purposes) where sufficient floor space was available, but for configurations where no experiment was shown, remaining floor space (freeboard) was noted as being available for such a task.

MISCELLANEOUS

No attempt was made to define or show the ducting, wiring or plumbing which may be required. Within each module, area and volume appeared available to support these items.

CONFIGURATION DESIGN

There were six (6) different module configurations studied. A study of the 15.0 Ft. Dia. module was conducted for module Types I, II, and III; the 17.5 Dia. module was studied for types I and II; and for the 21.67 Ft. Dia., only Type I was studied. A brief description of each configuration is shown below and module capability is shown in Table 1.

CONFIGURATION 1

This is a 15.0 Ft. Dia. Type I configuration as shown in Figure 3.

The basic compartment contains:

- Living quarters for 2 men and gear
- Sanitary Facilities
- Social and Dining Area
- Air Lock
- Control Consoles

The equipment bay contains:

- Food
- EC/LS System
- Spares
- Recreation Equipment

This configuration has approximately 34 Ft^2 of floor space remaining, equivalent to a 5.5 Ft. by 6 Ft. room. With this limited available floor space, no consideration was given to experiments.

CONFIGURATION 2

This is a 15.0 Ft. Dia. Type II configuration as shown in Figure 3.

The lower deck contains:

- Living quarters for 2 men and gear
- Sanitary Facilities
- Air Lock

The upper deck contains:

- EC/LS System
- Mission Control Consoles
- Social and Dining Area
- Spares
- Recreation Equipment
- Food

This configuration has 140 Ft^2 of floor space remaining 46 Ft^2 can be made available for experimental purposes. Here, it should be noted, if food requirements are re-supplyable, approximately 30 Ft^2 of floor space would be available for either experiment or possibly an additional crew member.

CONFIGURATION 3

This is a 15.0 Ft. Dia. Type III configuration as shown in Figure 4.

The lower deck contains:

- Living quarters for 3 men and gear
- One Control Console
- Sanitary Facilities
- Social and Dining Area
- Recreation Storage Area

The upper deck contains:

- Air Lock
- One Control Console
- Experiments*
  - -IMBLMS
  - -LBNP

*As shown in Saturn V orbital workshop study.

The equipment bay contains:

- EC/LS System
- Food Storage
- Spares

This configuration depicts a mission module which can support all the required functions such as crew, experiments and long mission duration supply. The 86 Ft^2 of remaining floor space is defined as available crew area.

CONFIGURATION 4

This is a 17.5 Ft. Dia. Type I configuration as shown in Figure 5.

The basic compartment contains:

- Living quarters for 3 men and gear
- Sanitary Facilities
- Social and Dining Area
- Mission Control Consoles
- Air Lock

The equipment bay contains

- EC/LS System
- Food
- Spares
- Recreation Equipment
- Storage Volume (Additional)

This configuration has approximately 66 Ft^2 of floor space remaining, equivalent to a 6 Ft. by 10 Ft. room. Again, as in configuration 1, this was considered insufficient freeboard to support any type of experiment and still provide crew area.

CONFIGURATION 5

This is a 17.5 Ft. Dia. Type II configuration as shonw in Figure 6.

The lower deck contains:

- Living quarters for 3 men and gear
- Sanitary Facilities
- Air Lock

The upper deck contains:

- Mission Control Consoles
- Social and Dining Area
- Spares
- EC/LS System
- Recreation Equipment
- Food

This configuration has 212 Ft^2 of floor space remaining of which about 53 Ft can be made available for experiment. Also, on the upper deck, as an optional configuration when food could be a re-supply item, an experiment arrangement could be provided as shown in Figure 6.

CONFIGURATION 6

This configuration is a 21.67 Ft. Dia. Type I configuration as shown in Figure 7.

The basic compartment contains:

- Living quarters for 4 men and gear
- Sanitary Facilities
- Mission Control Consoles
- Social and Dining Area
- Air Lock

The equipment bay contains:

- EC/LS System
- Food
- Spares
- Recreation Equipment
- Storage Area (Additional)

This configuration has 172 Ft^2 of floor space remaining of which about 55 Ft^2 can be made available for experiment. The 117 Ft^2 of remaining floor space is defined as available crew area. Also, in the equipment bay, approximately 250 Ft^3 of storage space is available for other equipment or experiment storage.

MODULE UTILIZATION

The volume and floor space for the different module configurations is shown in Table 2. The data in this table defines the available spatial and volumetric content for the pressure shell part of the module.

The spatial and volumetric utilization for the different configurations is shown in Table 3.

For the comparative crew volume utilization of the different configurations studied, see Table 4.

The significant point illustrated by these tables is that the module volume can have multiple uses. The module in stripped form can be a spacious experiment shell. Alternately, removal of experiment space, consoles, and/or food provides space for more crewmen. The projected module capabilities are tentative since control console requirements are undefined and the required free space per man is uncertain.

A. S. Kiersarsky

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Attachments

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5. Gorman, R., "Informal Notes of Mans Daily Requirements and Regenerative EC/LS Systems".

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TABLE 1

BASELINE MODULE CAPABILITY

CONFIGURATIONS	MODULE DIAMETER	MODULE ARRANGEMENT TYPE	BASELINE CREW SIZE	LIVING QUARTERS (INDIVIDUAL)	SPACECRAFT & MISSION CONTROL	EXPERIMENTS CAPABILITY
1	15.0 Ft.	I	Two Men	Yes	Yes	No
2	15.0 Ft.	II	Two Men	Yes	Yes	Yes
3	15.0 Ft.	III	Three Men	Yes	Yes	Yes
4	17.5 Ft.	I	Three Men	Yes	Yes	No
5	17.5 Ft.	II	Three Men	Yes	Yes	Yes
6	21.67 Ft.	I	Four Men	Yes	Yes	Yes

TABLE 2

MODULE VOLUME AND FLOOR SPACE

CONFIGURATIONS	VOLUME				FLOOR SPACE		
	LOWER DECK (SINGLE DECK) FT^3	UPPER DECK FT^3	EQUIPMENT BAY FT^3	TOTAL VOLUME FT^3	LOWER DECK FT^2	UPPER DECK FT^2	TOTAL FT^2
1	994 *	-	306	1300	153 *	-	153
2	994 *	994	-	1988	153 *	153	306
3	994 *	994	458	2446	153 *	153	306
4	1380 *	-	424	1804	212 *	-	212
5	1380 *	1380	-	2760	212 *	212	424
6	2028 *	-	717	2745	312 *	-	312

*Floor Space and Volume Available if used as Experiment Container

TABLE 3

SPATIAL AND VOLUMETRIC UTILIZATION

CREW SIZE	Config. 1		Config. 2		Config. 3		Config. 4		Config. 5		Config. 6	
	$Ft.^2$	$Ft.^3$	$Ft.^2$	$Ft.^3$	$Ft.^2$	$Ft.^3$	$Ft.^2$	$Ft.^3$	$Ft.^2$	$Ft.^3$	$Ft.^2$	$Ft.^3$
Sleeping Qtrs. & Gear Stowage	25	162	25	162	37.5	244	37.5	244	37.5	244	50	325
Control Consoles	34	216	34	216	34	216	34	216	34	216	34	216
Airlock	14.5	95	14.5	95	22	142	22	142	22	142	26.5	172
Airlock Protect. & Stowage Area	12	78	12	78	14.5	94	14.5	94	14.5	94	15.5	100
Hygiene	8.5	55	8.5	55	9	59	9	59	9	59	9.5	62
Waste & Waste Maste Manage.	11	71	11	71	11.5	75	11.5	75	11.5	75	12.0	78
Dining & Social Area	14	91	14	91	16	104	17.5	114	20	130	25	162
EC/LS*	-	90	14	90	-	100	-	100	16	100	-	110
Food*	-	150	24	150	-	225	-	225	38.5	225	-	300
Recreation*	-	30	4.5	30	-	30	-	30	4.5	30	-	35
Spares*	-	30	4.5	30	-	30	-	30	4.5	30	-	35
Experiment	-	-	-	-	76	496	-	-				
Total Floor Space Available	153		306		306		212		424		312	
Total Floor Space Used	119		166		220		146		212		172	
Floor Space Remaining	34		140		*** 86		66		212		140	
Total Volume Available**		1300		1988		2446		1804		2760		2745
Total Volume Used		1068		1068		1815		1329		1345		1595
% Utilization	77%	82%	54%	53%	71%	74%	69%	73%	50%	48%	55%	58%

* For Configurations 1,3,4 & 6 only the volumetric requirements are shown since floor space in the equipment bays serves no other useful purpose.

**For Configurations 1,3,4 & 6 this volume includes equipment bays.

***Floor Space remaining with experiment capability integrated.

TABLE 4

CREW VOLUME UTILIZATION

CONFIGURATIONS	PRESSURIZED VOL. (GROSS) FT^3	BASELINE CREW SIZE	EXPERIMENT VOL. & MISSION CONTROL FT^3	NET VOLUME FT^3	VOL/MAN FT^3	MAXIMUM CREW SIZE WITHOUT EXPERIMENTS	MAXIMUM CREW SIZE WITHOUT EXPERIMENTS OR MISSION CONTROL	MAX. CREW SIZE WITHOUT EXP. MIS. CONT. & WITH 30 DAY FOOD SUPPLY
1	1300	2	216	1084	542	2	2	3
2	1988	2	300 + 216	1472	736	3	4?	4
3	2446	3	496 + 216	1734	574	4	5?	5
4	1804	3	216	1588	529	3	3	4
5	2760	3	345 + 216	2199	733	4	5	6
6	2745	4	345 + 216	2184	546	5?	5	6

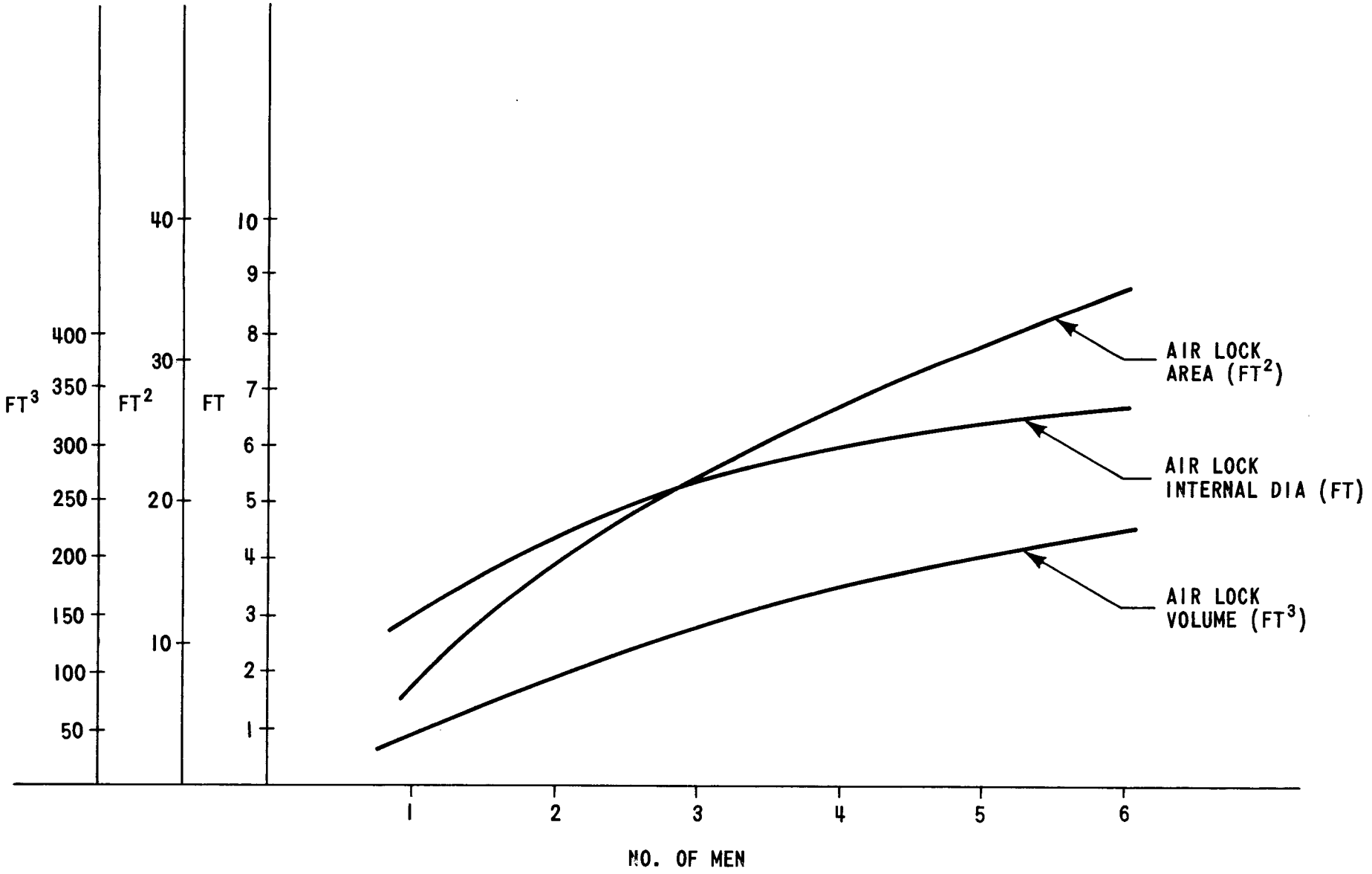


FIGURE I - AIR LOCK SIZES VS. NO. OF MEN

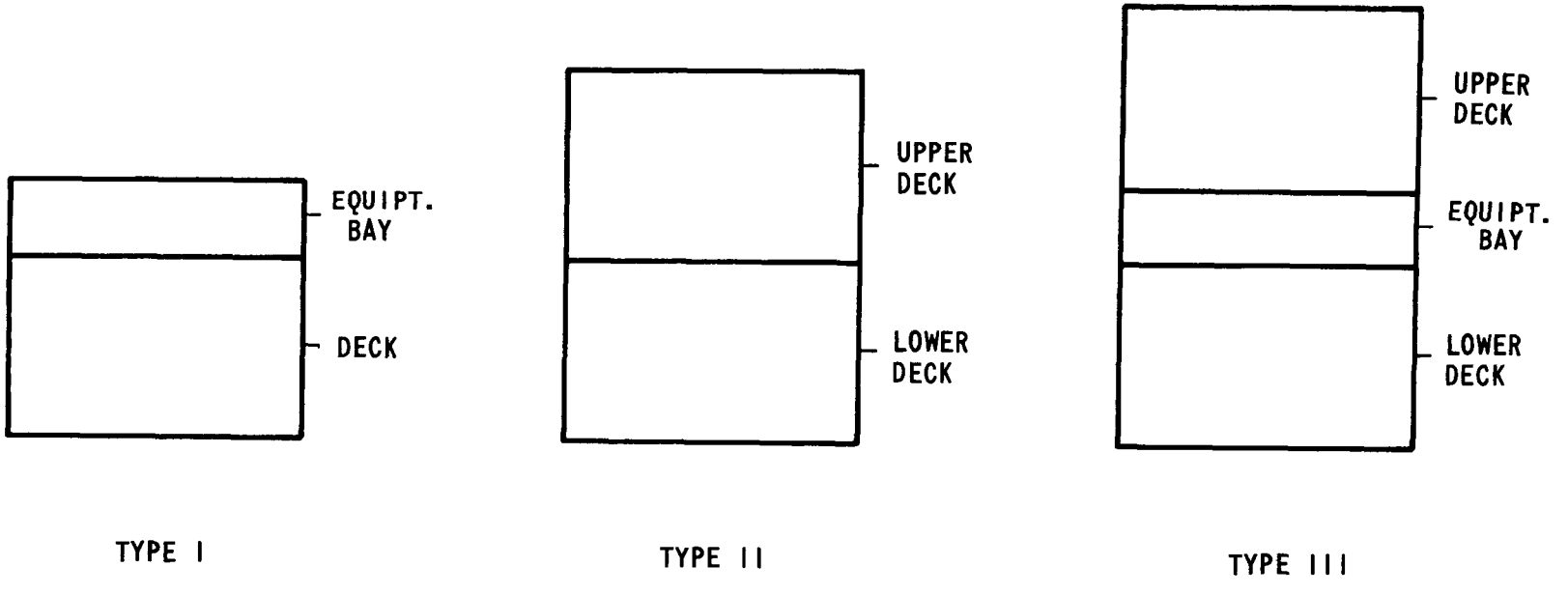


FIGURE 2 - MODULE TYPES

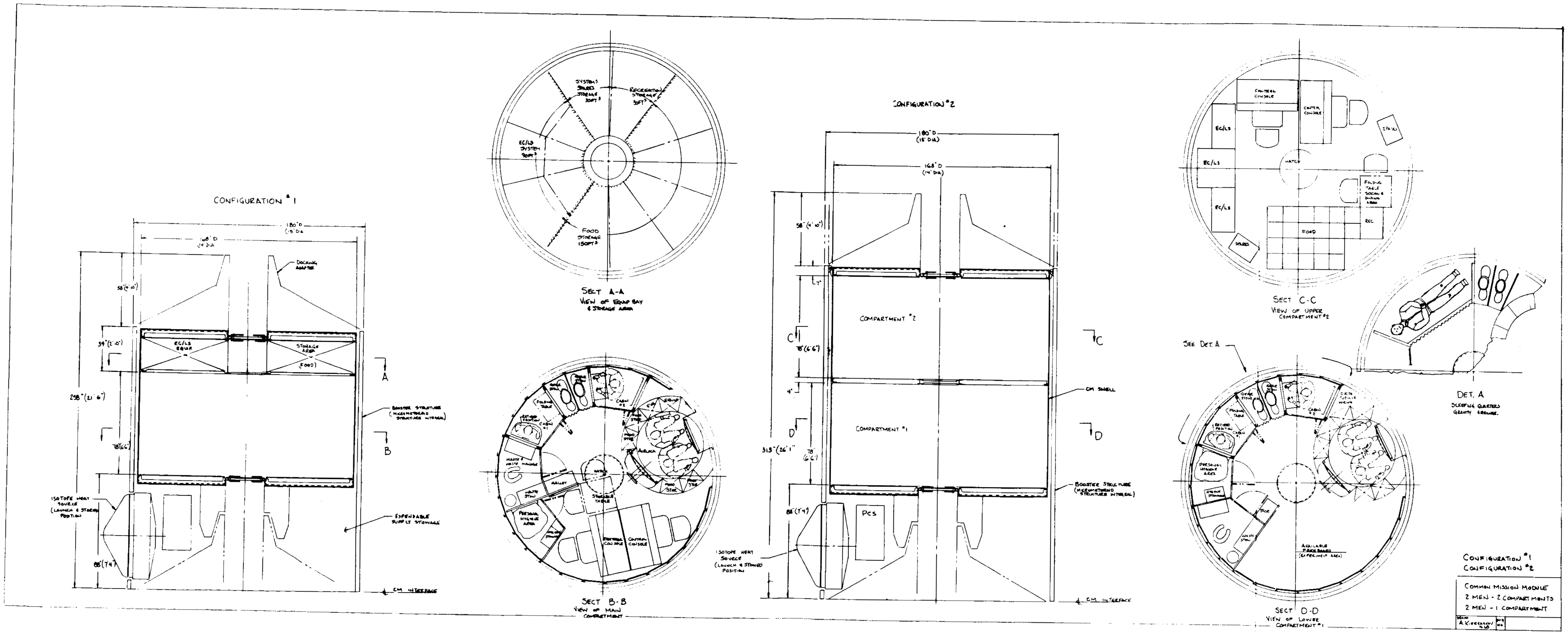
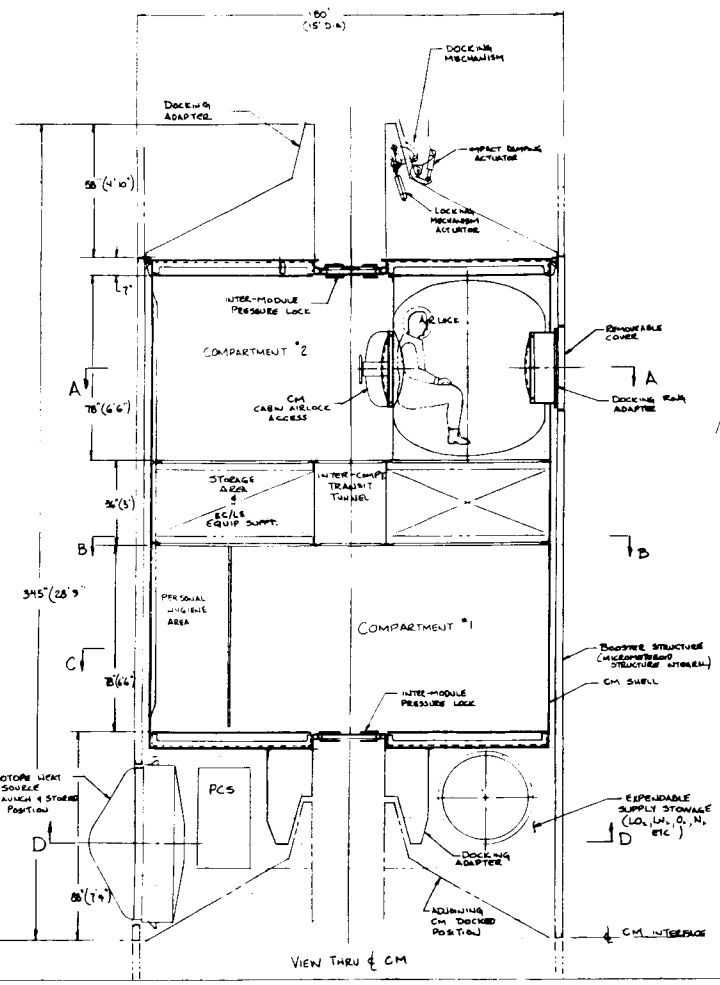
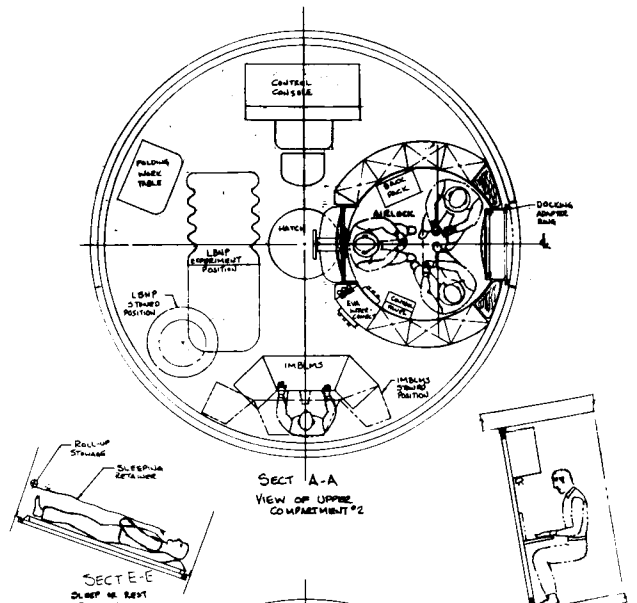


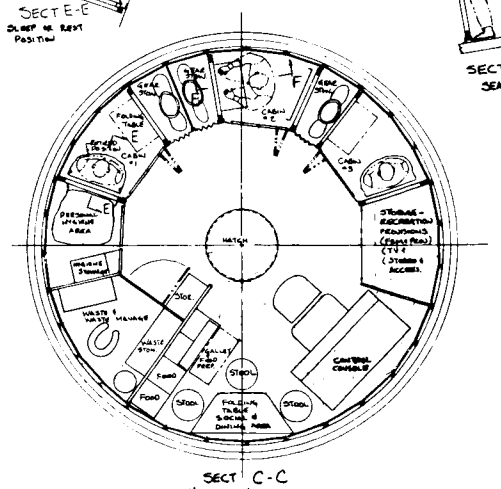
FIGURE 3

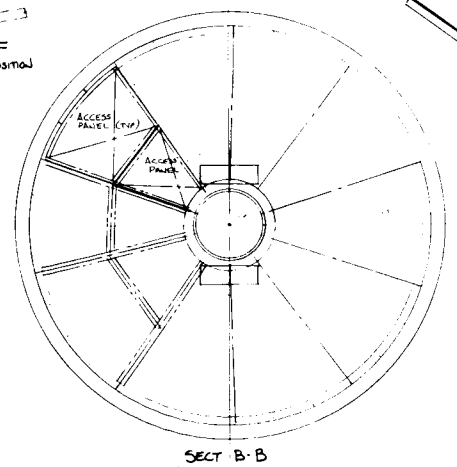
FOLDOUT FRAME 1

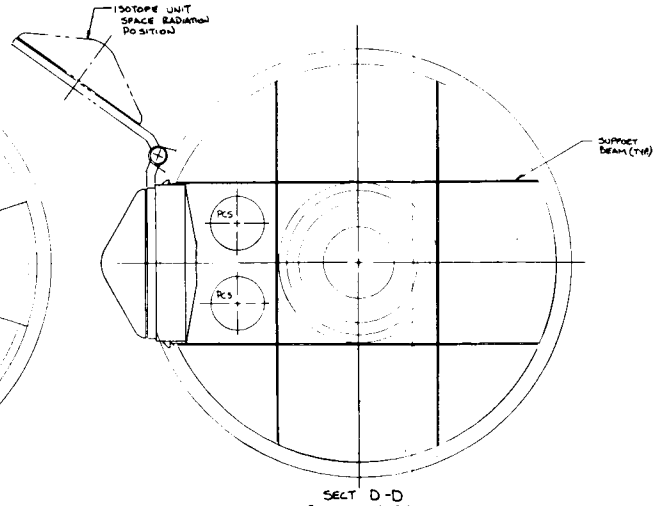
FOLDOUT FRAME 2











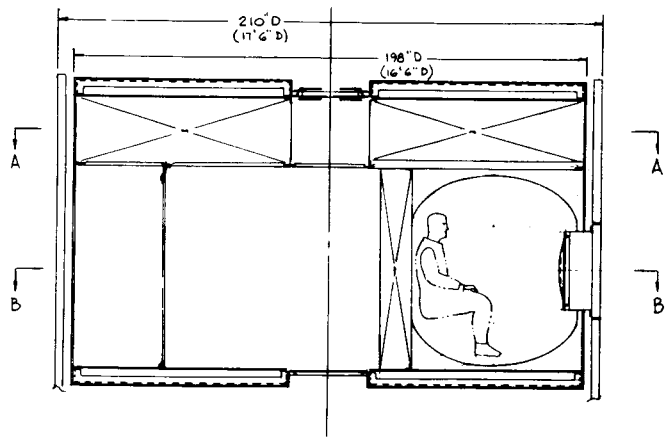
CONFIGURATION "3
COMMON MISSION MODULE -
3 MEN - 2 COMPARTMENTS

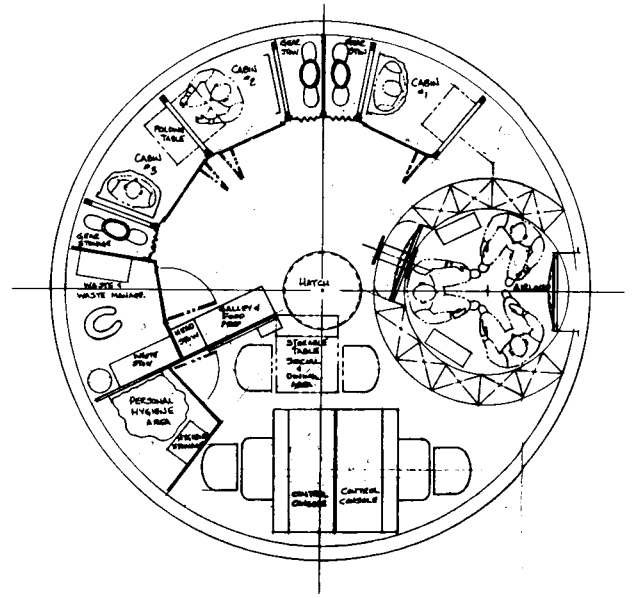
A. KEEDY 4-68

FIGURE 4

FOLDOUT FRAME 1

FOLDOUT FRAME 2





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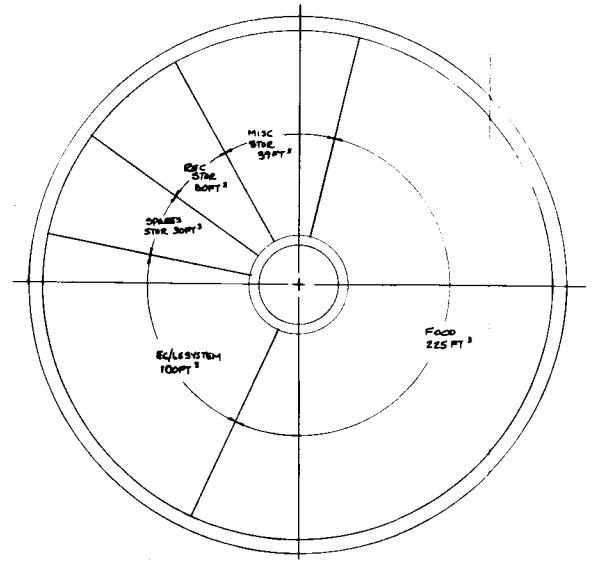


SECT A-A

CONFIGURATION #4

COMMON MISSION MODULE
3 MEN - 1 COMPARTMENT

FIGURE 5

FOLDOUT FRAME 1

FOLDOUT FRAME 2

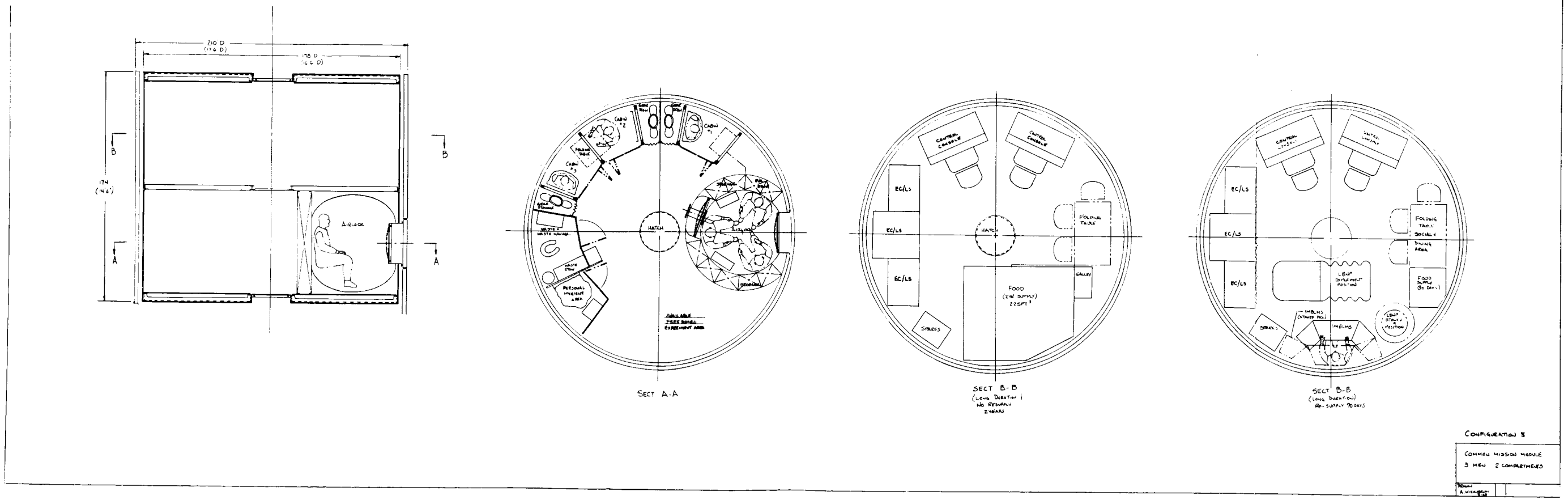
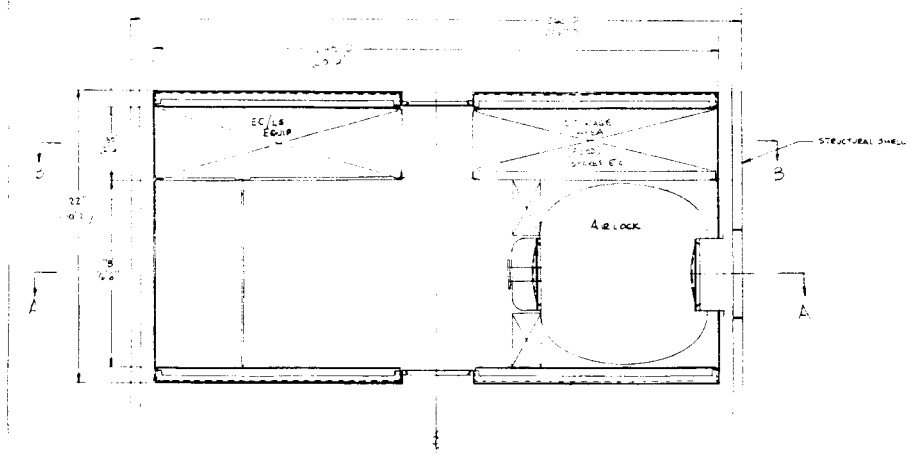
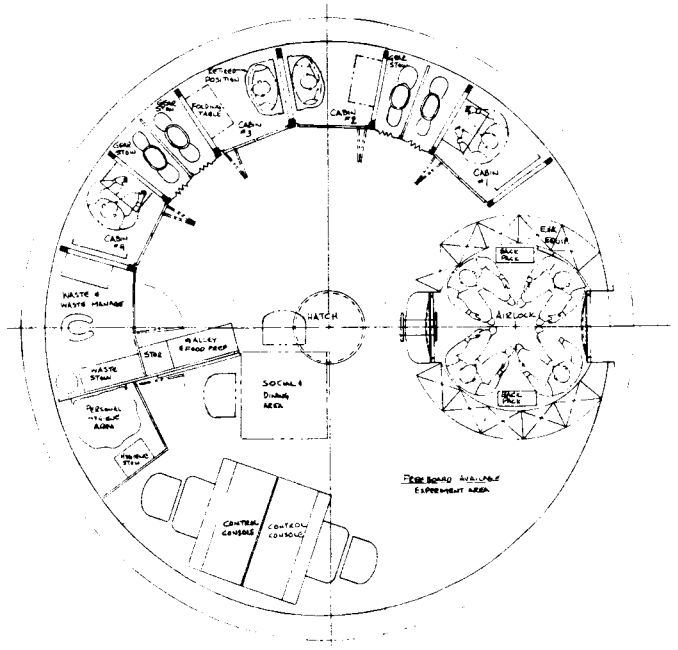


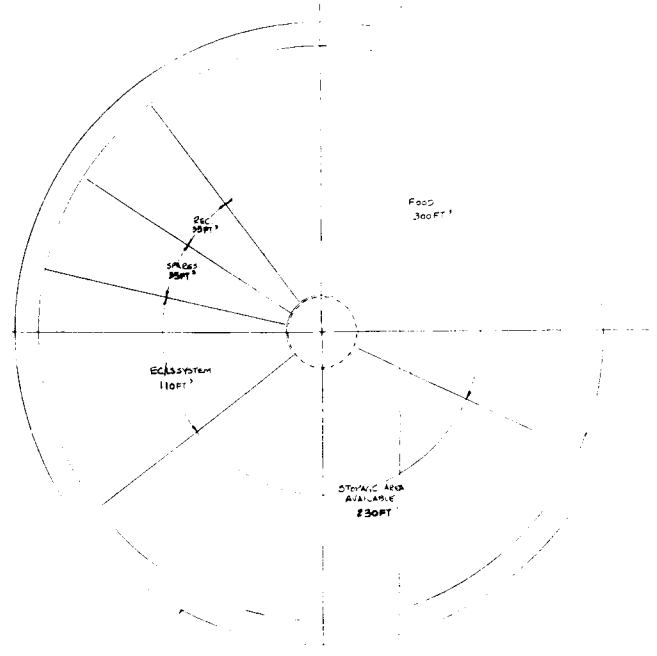
FIGURE 6

FOLDOUT FRAME 1

FOLDOUT FRAME 2







CONFIGURATION "G"

COMMON MISSION MODULE
4 MEN 1 COMPARTMENT

FIGURE 7

FOLDOUT FRAME 1

FOLDOUT FRAME 2